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The Effects of Two Different Sports Drinks on RPE and Finishing Speed of an Endurance Run in Highly Trained Distance Runners

Matthew J. Feldhake
Eastern Illinois University

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The Effects of Two Different Sports Drinks on RPE and Finishing Speed

of an Endurance Run in Highly Trained Distance Runners

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BY

Matthew J. Feldhake

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Abstract

The purpose of this study was to compare the effects of a protein-containing sport drink with a traditional non-protein sport drink has on ratings of perceived exertion (RPE) and finishing speed of an half marathon. Of the possible factors that would support including protein in a sport drink the primary one was its inhibitory effect on serotonin release in the brain. This could help attenuate perceived exertion, thus allowing individuals to compete at a higher level for longer durations (Davis, Alderson, & Welsh, 2000).

This study was conducted using nine members of the Eastern Illinois University Men's Cross Country team. Subjects completed two separate 13.1 mile runs on a flat, crushed limestone path, consuming 4 ounces of either a carbohydrate and protein (CHO-P) or non-protein (CHO) containing sport drink every three miles as assigned by the primary researcher. The study used a single-blind design so the subjects did not know which sport drink they were receiving during each trial. RPE scores were obtained at the halfway point and at the finish line. Finishing speed was also recorded as the speed over the last 1.1 miles of the 13.1 mile run were at a "race pace" effort.

During the second trial, the two groups were given the other sport drink in a crossover design. For purposes of data analysis, subjects were analyzed in four groups (CHO1, CHO-P1, CHO-P2, and CHO2) based upon the sport drink they consumed each trial.

A MANOVA with a Tukey post-hoc test was used to analyze intergroup statistics using SPSS statistical software (version 22.0). The results showed no

significant differences between the two groups for RPE and finishing speed at the end of an endurance run. Therefore, there was no benefit was observed in RPE or finishing speed of an endurance run from having protein in a CHO sport drink. Confounding factors include slight differences in weather between trials, differences in individual nutrition and sleep habits between trials, and different levels of effort between the trials. In conclusion, this study found no added benefit of a carbohydrate-protein sport drink compared to a traditional carbohydrate sport drink on RPE or finishing speed at the end of an endurance run.

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Table of Contents

List of Tables

Chapter I

Introduction

Statement of the Problem

The use of ergogenic aids in endurance running is, and has always been, an evolving science particularly when it comes to fluid replacement strategies. Originally, it was believed that water alone was enough to fuel endurance runners (Fallowfield, Williams, Booth, Choo, & Growns, 1996). Today, sport drinks such as Gatorade®, PowerAde®, and Accelerade® are widely used ergogenic aids, which by definition are intended to help improve performance physically or mentally. Athletes hope the use of such sport drinks can help them maximize the full benefits of training, giving them a competitive edge in competition. Research has shown that, compared to water, consuming sport drinks during exercise can aid performance by improving blood glucose uptake by the muscles utilized during exercise, preserving central nervous system (CNS) substrate delivery (Coyle et al.,1983; Nybo, 2003) by replenishing muscle glycogen stores (Williams, Raven, Fogt, & Ivy, 2003), or by repairing muscle breakdown during the recovery phase allowing an individual to recover at a faster rate, thus being able to perform more workouts in a training period. (Levenhagen, et al., 2002).

Today, carbohydrate (CHO) sport drinks and sports beverages such as Gatorade® and PowerAde® are widely popular means to provide needed fuel during endurance activity, while carbohydrate-protein (CHO-P) beverages such as chocolate milk and Accelerade® are seen primarily as a means for post-exercise recovery (Saunders, 2007). Studies by Desbrow, Anderson, Barrett, Rao, and Hargreaves (2004), and Carter, Jeukendrup, and Jones (2004) have shown that compared to water, CHO sports drinks provide greater performance benefits such as reduced race time and time to exhaustion when endurance activities last an hour or longer and are of moderate-vigorous intensity. Additional research has begun to assess whether the consumption of a CHO-P sport drink during endurance exercise would provide greater performance benefits compared to a CHO-only sport drink (Ferguson-Stegall et al., 2010; Ivy, Res, Sprague, & Widzer 2003; McCleave et al., 2011). Studies have revealed that CHO-P supplementation can cause an increase in leg glucose uptake (Levenhaen et al., 2002), as well as an increase in protein oxidation in comparison to CHO (Koopman et al., 2004). This increase in protein oxidation, although it has not been tested, could potentially decrease the use of muscle glycogen in late exercise due to altering substrate utilization (Saunders, 2007). According to Kreider, Fry, and O'Toole (1998), CHO-P ingestion during prolonged endurance activity could potentially play a vital role in delaying fatigue by minimizing the increase in the free tryptophan to branched chain amino acid (fTryp/BCAA) ratio and the synthesis of serotonin. Due to the fact that free tryptophan (fTryp) and branched chain amino acids (BCAA) compete for the same transporter to the brain, an increase in BCAA could lower the amount of fTryp transported into the brain, and would ultimately reduce the synthesis and release of serotonin (Kreider et al., 1998). This reduction in serotonin release could potentially improve exercise due to its link to CNS fatigue (Davis et al., 2000). Serotonin levels have been shown to increase with prolonged exercise, and because serotonin has well-known effects on mood, arousal, lethargy, and sleepiness it has been associated with fatigue during exercise (Davis, et al., 2000). Reducing CNS fatigue would theoretically lead to a reduction in perceived exertion level. While perceived exertion can be impacted by physiological mechanisms, it is believed to a motor control strategy of the nervous system to control pacing and avoid permanent tissue damage (Batson, 2013). Thus far, the research has provided varied results in performance benefits when comparing CHO to CHO-P sport drinks (Ivy et al., 2003). This can be attributed in part to variations in research methodology and protocol such as variances in the methodology included: differences in sport drink content (isocaloric vs. isocarbohydrate), type of testing (time trial vs. time to exhaustion), and use of or absence of a placebo (Toone, & Betts, 2010). It is clear, that more research is warranted to address the aforementioned gaps in the literature.

Research Questions & Hypotheses.

Question 1: Does CHO-P sport drink lower RPE in endurance activity in highly trained runners?

Question 2: Does CHO-P sport drink improve finishing speed at the end of an endurance run in highly trained endurance runners?

It was hypothesized that the consumption of a protein containing CHO sport drink during a 13.1 mile running performance would improve finishing speed in highly trained endurance runners more so than that of a simple CHO sport drink. Furthermore, it was hypothesized that CHO-P would lower RPE midway through and at the end of the same performance.

Purpose of the study

The purpose of this study was to compare the finishing speed and rating of perceived exertion (RPE) between CHO and CHO-P sport drinks in highly trained endurance runners over a 13.1 mile run in highly trained collegiate athletes.

Rationale for the study

This study was designed to help provide evidence as to whether the addition of protein to a normal CHO beverage can help improve finishing speed at the end of an endurance run by enhancing certain physiological factors and responses such as maintaining fluid-electrolyte balance and Krebs cycle intermediates. This study also aimed to determine whether the addition of protein to a CHO sport drink improved perceived exertion during a running time-trial. Since, few studies have incorporated both time-trial and isocaloric methodologies, this study addressed gaps in the study of fluid replacement in endurance athletes thus making this study significant in supplementing the existing literature (Ivy et al., 2003; Toone & Betts, 2010).

There are many physiological factors that play an important role in endurance activity (Coyle, 1999), some of which can be enhanced by the addition of protein. For example, it is important to maintain fluid-electrolyte balance during endurance activities. Endurance athletes may lose a large amount of fluid through sweat, making it hard to maintain this balance; however, the consumption of CHO-P can help maintain this balance (Lamont, 2003). Proteins help maintain fluid-electrolyte balance by enhancing the absorption of electrolytes such as sodium, and water in the gut (Leser, 2011). An increased plasma protein concentration will then result in a higher oncotic pressure allowing water to flow across a gradient and into the circulatory system (Leser, 2011).

The addition of proteins to a CHO only sport drink may also improve the maintenance of Krebs cycle intermediates (McCleave et al., 2011). The maintenance of these intermediates is critical to maintaining aerobic energy production in the mitochondria.

Mental fatigue is a critical factor that can limit physical activity of all varieties, especially endurance activity. Research by Marcora, Staiano, & Manning (2009) showed that mental fatigue can actually impair subsequent physical performance. Individuals were asked to cycle to exhaustion at 80% of their peak power output after performing 90 minutes of a demanding cognitive task (mental fatigue) or 90 minutes of watching an emotionally neutral documentary (control). Their study showed that total time to exhaustion (TTE) was significantly lower after subjects performed the demanding cognitive task (640± 316 s) in comparison to the control (754 ± 339 s.) (Marcora, Staiano, & Manning, 2009). Thus, if mental fatigue can be reduced, athletes should be able to improve their physical performance. Stimuli for muscle contractions are initiated in the brain, thus fatigue can occur if changes within the CNS inhibit the ability of the brain to generate and transmit signals to the muscle (Davis et al., 2000). This is referred to as central fatigue or CNS fatigue. According to Davis, Alderson, and Welsh (2000), the neurotransmitter serotonin (5-HT) is likely involved in CNS fatigue because of the critical role it plays in depression, sensory perception, sleepiness, and mood. It has been shown that the addition of protein to a CHO sports beverage may possibly help minimize fatigue by reducing the synthesis of serotonin within the CNS (Kreider et al., 1998). However, there is little research looking at the impact this inhibition of serotonin has on perceived exertion. Furthermore, research is limited on the effects this would have on finishing speed of an endurance run in highly trained distance runners.

Significance of the study

Hundreds of thousands of individuals compete in endurance competitions in the United States every year (RunningUSA, 2018). This large number of participants has continued to lead to an increase in competition level. This is evident by the constantly improving Boston Marathon qualifying time (BAA.org). With this rise in competition at major races, runners are looking for means to improve performance. Therefore, more research on ergogenic aids and the potential benefits of various sports drinks on endurance running performance is necessary.

This study analyzed both not only perceived exertion but finishing speed of an endurance run as well. Thus, this is one of few studies that examined both physical performance and perceived exertion in a competitive race situation. Since perceived exertion can limit physical performance, it is important to understand whether the addition of protein can help runners feel better during endurance running by lowering their perceived effort levels (Marcora, Staiano, & Manning 2009) and whether this leads to an improvement in performance.

Limitations

The following limitations reduce the ability to generalize the results of this specific study:

1) The mixtures were isocaloric, thus the CHO mixture had a greater amount of CHO than the CHO-P mixture. Since CHO is the primary fuel oxidized by the muscles during exercise, a greater amount of calories from CHO may or may not have been an advantage to the CHO group.
2) The Borg CR 10 Scale is only one means of acquiring an individual's RPE and may not completely reflect a person's true perceived exertion.
3) Data was collected outside during the month of November when weather conditions were similar for each trial but no equal.

Delimitations

1.) This study was conducted using highly trained male distance runners.

2.) Subjects were members of Eastern Illinois University Men's Cross Country team.

3.) Most subjects were former teammates of the primary researcher.

Basic Assumptions

1.) It was assumed that subjects ran a normal training pace through the first 12 miles in both trials.

2.) It was assumed that subjects gave a 100% race pace effort the last 1.1 miles in both trials.

3.) It was assumed that subjects consumed all contents of their given sports beverage according to study protocol.

4.) It was assumed training and diet remained similar and constant in the days before each trial.

Definition of Terms

Branched Chain Amino Acids (BCAA): three essential amino acids (leucine, isoleucine, and valine) that allow blood glucose to be taken up by the muscle, help with muscle recovery, and can help delay CNS fatigue by inhibiting the release of serotonin in the brain.

Borg Scale: a specific scale used to quantify an individual's subjective level of perceived exertion that can be either a 0-10 scale or a 6-20 scale.

Central Nervous System (CNS): system of the human body containing the brain and spinal cord that receives sensory information and controls the body's responses to that information.

Ergogenic aid: an external influence, such as a sports beverage, caffeine, steroids, or creatine, that can improve or enhance physical and/or mental performance.

Free tryptophan *(fTryp):* an essential amino acid that is a precursor to serotonin synthesis.

fTryp/BCAA ratio: the ratio of free tryptophan (a precursor to serotonin) to branched chain amino acids often measured in its relationship to central nervous system fatigue.

Isocaloric: where two beverages contain the same number of calories.

Isocarbohydrate: where two beverages contain the same carbohydrate content.

Neurotransmitter: a substance that transmits nerve impulses, typically across a synapse.

Oncotic Pressure: pressure exerted by proteins in a blood vessel's (typically the capillaries) plasma that influences the movement of water.

Rating of Perceived Exertion (RPE): a rating scale used to self-assess fatigue and intensity during exercise.

Serotonin: a neurotransmitter that has many functions such as regulating mood, appetite, and sleep. It has also been shown to increase during exercise and is closely associated with CNS fatigue during prolonged activity.

Chapter II

Literature Review

This literature review focuses on the following aspects related to the current study: (a) benefits and physiological responses of carbohydrate supplementation during endurance activity, (b) benefits and physiological responses of carbohydrate-protein (CHO-P) supplementation during recovery, (c) benefits and physiological responses of CHO-P supplementation during endurance activity, and (d) summary, gaps, and future direction.

Benefits and Physiological Responses of CHO Supplementation during Endurance Activity

Traditionally, CHO-P mixtures are used primarily in recovery, whereas liquid carbohydrate (CHO) sport drinks such as Gatorade® and PowerAde® are used during endurance competitions and training to improve performance by minimizing dehydration, maintaining blood glucose levels, and replacing lost electrolytes. It has been well documented that the consumption of CHO sport drinks improves endurance performance lasting 80-90 minutes or longer in comparison to water (Coombes & Hamilton, 2000; el-Sayed, MacLaren, & Rattu, 1997; & Jeukendrup, 2004). A review study by Coggan and Coyle (1991) observed that CHO ingestion during prolonged exercise enhanced performance primarily by maintaining the availability of blood glucose. These same authors also observed a positive correlation between blood glucose utilization and exercise duration. As exercise duration increases, the utilization of blood glucose as a fuel source also increases. Thus, since carbohydrate feeding during exercise can increase the availability of blood glucose, which becomes the primary fuel source during endurance exercise, it is logical that an increase in performance would be observed. (Coggan & Coyle, 1991). In fact, most major marathons offer CHO sport drinks at their hydration stations in light of this research (Chicago Marathon 2016 Subjects Guide).

The uptake of blood glucose is important because it can provide both anaerobic and aerobic energy toward adenosine triphosphate (ATP) synthesis inside muscle fibers. Since only a small amount of ATP is available inside the muscle fiber, ATP constantly needs to be re-synthesized from carbohydrate, fat or protein sources. Of those three, energy from carbohydrate is transferred to ATP at a faster rate and therefore is the preferred fuel for ATP synthesis during moderate to intense exercise. One drawback to carbohydrate as an energy source is the limited amount stored inside muscle fibers particularly in events lasting 90 minutes or longer (Coyle et al., 1983). Coyle et al. (1983), required 10 experienced, competitive cyclists (9 men, 1 woman) to pedal at 70-79% of their maximal oxygen uptake (VO2max) until time to fatigue. When the cyclists could no longer maintain the prescribed intensity, they were permitted to decrease the workload by 100-kpm/min decrements until they were at a workload that they thought they could exercise at for an additional 10 minutes. This process was repeated until the subjects fell below 50% of their VO2max or 180 minutes of exercise had been reached. Fatigue was defined as "the time at which the exercise intensity that the subjects could maintain decreased below their initial work rate by 10% of VO2max". The cyclists performed the bicycle ergometer test on three occasions separated by a week. The first trial served as a familiarization phase for the subjects. In trials 2 and 3, the cyclists received either a polycose solution or a placebo of similar flavor and consistency. After the first 20 minutes, the subjects received 1.0 g. carbohydrates/kg body weight of a 50% polycose solution. Following 60,90 and 120 minutes of exercise the subjects received a 6% polycose solution which provided 0.25 g. carbohydrates/kg of body weight. Blood was drawn throughout the course of the study via a catheter inserted into the antecubital vein to test blood glucose levels. This blood was draw prior to the exercise and at minutes 10, 30, 90, 120, 150, and the last minute of exercise. The results of this study showed that CHO supplementation significantly ($p<0.001$) improved performance (126 ± 3 minutes compared to 159 ± 6 minutes) by showing an increase in time to exhaustion between exercise without carbohydrate feeding and exercise with carbohydrate feeding. The increase in time to exhaustion may have occurred by an enhancement in the uptake of blood glucose by the working muscles (2.9 vs. 4.4 mM at time of fatigue), as well as helping maintain the delivery of glucose to the central nervous system (CNS).

Similarly, Nybo (2003), found glucose supplementation had a significant impact on delaying CNS fatigue. The subjects in this study were eight endurance-trained males with a mean (± SE) age of 27 ± 2 years, height of 182 ± 3 cm, weight of 75 ± 3 kg, and a $VO2_{max}$ of 66 ± 2 mL kg^{-1} min^{-1}. The subjects performed two trials on an ergometer for 3 hours at 60% of their pre-determined

VO2max. During one trial the subjects consumed a 6% glucose polymer solution every 15 minutes (CHO), whereas during the other trial subjects consumed an equal volume of noncaloric placebo drink sweetened with cyclamate and saccharine (PLA). Prior to each trial, subjects were asked to maintain normal training habits, as well as abstain from tea, coffee, and other caffeinated beverages. On the day of each trial, subjects were fitted with a HR monitor and a catheter was inserted in a superficial vein in the hand. Venous blood samples were drawn after each hour of exercise. Pre-exercise maximal voluntary muscle contraction (MVC) was determined as the best of three maximal isometric contractions utilizing the extensors of the knee. Immediately following the cycling protocol, subjects were seated and were asked to maintain a MVC of the knee extensors for two minutes. Subjects were verbally encouraged to give a maximal effort at all times. The force of the knee extensors was measured as the changes in voltage detected by a strain gauge dynamometer. An electrical stimulus with intensity 20% higher than that needed to create a maximal twitch was superimposed every 30 seconds during the MVC testing. This allowed the researchers to separate the role of the CNS from the peripheral nervous system on muscle contraction.

Initial blood glucose levels were similar on both experimental days (4.5-4.6 $\pm$ 0.2 mmol $\cdot L^{-1}$) and glucose levels were maintained throughout the cycling protocol when consuming the CHO supplementation. However, in the PLA trial blood glucose levels significantly decreased throughout the course of the exercise protocol (3.0 $\pm$ 0.2 mmol $\cdot L^{-1}$). Hemoglobin and Na^+ concentrations remained constant throughout both trials showing that hydration status was consistent. MVC was also significantly reduced between the CHO (222 ± 20 N) and PLA (197 ± 21 N) trials, and both were significantly lower than the pre-exercise value (248 ± 23 N). The results of this study indicate that in endurance-trained males, the onset of hypoglycemia during endurance exercise is associated with an impairment of CNS drive during sustained isometric contractions resulting in a decrease in muscle force production, however, the decrease in force production is mitigated by consuming a CHO beverage.

Another benefit to oral consumption of a CHO supplement during exercise is its potential in attenuating an increase in ammonia production during prolonged endurance exercise (Snow, Carey, Stathis, Febbraio, & Hargreaves, 2000; Carvalho-Peixoto, Alves, & Cameron, 2007). Muscle ammonia (NH3) production occurs when the rate of ATP utilization outweighs the rate of ATP synthesis from carbohydrate and involves the activation of AMP deaminase which converts amino acids into cellular energy to help meet the ATP requirements of the contracting muscle. A by-product of amino acid breakdown is ammonia. Muscle ammonia levels have been found to increase in the body during prolonged, high intensity activities (Snow et al., 2000). High levels of ammonia are shown to inhibit neurotransmission, circulation, and even cerebral metabolism, thus limiting endurance performance (Banister & Cameron, 1990). Also, according to Schulz and Hermann (2003), increases in muscle ammonia levels can also cause fatigue by decreasing glycogen stores and therefore its availability during endurance events. Dombro, Hutson, and Norenberg (1993), showed that during a 24-hour period of ammonia feeding, peak glycogen stores were significantly decreased suggesting an inhibitory effect on glycogen synthesis. Snow et al. (2000) tested the effects of CHO ingestion on ammonia metabolism during exercise in two parts. In the first part, 8 endurance-trained men volunteered to exercise for 120 minutes at a workload of 65% of VO2peak on a cycle ergometer during which blood samples and cardiorespiratory data were obtained. Subsequently, two of these participants and three more participants volunteered to undertake the same exercise protocol with muscle sampling, therefore, a total of 11 subjects were tested having a mean age, weight, and peak pulmonary oxygen consumption (VO2peak) of 27.7 ± 1.6 yr, 69.8 ± 1.7 kg, and 4.40 ± 0.08 l/min, respectively. At least one week prior to the trials, each participant was required to perform an incremental maximal exercise test on a Monark cycle ergometer to determine their VO2peak. Participants were then tested on two separate occasions at least one week apart in a randomized order. During one trial, participants ingested 250 ml of an 8% carbohydrate-electrolyte solution at the start of exercise, and every 15 minutes thereafter for 120 minutes at an exercise intensity of 65% of VO2peak (CHO group). The participants in the control group received an equal volume of a sweet tasting, CHO-free placebo. During each trial, blood samples were obtained from an indwelling Teflon catheter inserted into a vein in the antecubital space. Samples were obtained at rest, and after 30, 60, 90, and 120 minutes of exercise. In the five participants in the second part of the study, muscle samples were also obtained from the vastus lateralis muscle by percutaneous needle biopsy at rest and after 30 and 120 minutes of exercise. The findings of this study show that blood glucose concentrations were similar at rest amongst the groups, but were elevated ($P<0.05$) in the CHO group compared to the control group at all sampling points during exercise. Furthermore, muscle ammonia concentration was not different at rest between the two groups, but was increased ($P<0.05$) at each subsequent measurement point in the control group. The results of this study indicate that carbohydrate ingestion elevated blood glucose concentrations and attenuates muscle and plasma ammonia accumulation during the latter stages of submaximal exercise. This can best be explained by carbohydrate ingestion reducing muscle ammonia production through a decrease in amino acid degredation and by maintaining a better balance between ATP degradation and resynthesis during the latter stages of exercise. It should be noted, however, that further research is needed to determine whether the reduction in tissue ammonia accumulation is due to the substance fed or due to the simple addition of energy (Snow et al., 2000).

Besides decreasing levels in ammonia, decreasing serotonin levels inside the CNS is another benefit of CHO intake during exercise which may help improve endurance performance since elevated serotonin levels are associated with fatigue (Davis, et al., 1992). Karelis, Smith, Passe, and Peronett (2010) proposed that a CHO supplement could help temper an increase in free fatty acid (FFA) and free tryptophan by stimulating the secretion of insulin. Since tryptophan is a precursor for the synthesis of serotonin, increased levels of free tryptophan could lead to an increase in serotonin production in the brain.

Throughout prolonged exercise, low levels of insulin are often observed which favors the release of FFA from adipose tissue. This release results in an increased plasma level of FFA and free tryptophan because FFA binds to albumin and displaces some of the albumin bound tryptophan. However, CHO ingestion during exercise stimulates the secretion of insulin which blunts the exercise-induced rise in FFA and free tryptophan. This decrease in free tryptophan levels would, in theory, reduce CNS fatigue by limiting the rise in serotonin levels in the brain. It is well established that serotonin plays a strong role in regulating an individual's mood and level of depression (Nordqvist, 2011). Davis et al., (1992) found that on average subjects showed a seven-fold increase in plasma free tryptophan levels when exercising at 68% VO2max for 200 minutes. This increase was associated with an increase in plasma FFA levels and a decrease in blood glucose concentrations from resting values (5 to 4 mmol $\bullet L^{-1}$). The consumption of 1g/min of CHO maintained blood glucose levels (5.5 mmol $\bullet L^{-1}$), as well as reducing fatigue by one hour. This delay in fatigue can be related to an attenuation of plasma free tryptophan and FFA.

Circulating glucose and lactate play a vital role in muscle contraction due to their importance as an energy source for the CNS during exercise (Karelis, Smith, Passe, & Peronnet, 2010). This provides reason to believe that supplementing with CHO during endurance activity can help maximize energy supply to the CNS.

Although the brain can metabolize various substrates, the most common fuel source for the brain is blood glucose. Therefore, the attenuation of hypoglycemia is another benefit of supplementing with CHO during endurance activity, however; results are mixed in determining whether it can improve performance (Karelis et al., 2010). But, since blood glucose is the primary fuel source for CNS function, and ultimately muscular contraction, it is assumed that limiting hypoglycemia and maximizing blood glucose levels, runners should improve their endurance. Nybo, Moller, Pedersen, Nielsen, and Secher (2003) looked at the role hypoglycemia plays in fatigue and the failure to preserve cerebral energy turnover or the rate at which the brain can uptake and utilize energy. They proposed that a reduction in blood glucose levels during prolonged exercise would alter cerebral metabolism and lead to early fatigue. In their study, six endurance trained males cycled at 60% of their predetermined VO2 max twice, once when given a CHO solution every 15 minutes, (0.7 grams/kg of body weight) and once when given a placebo (PLA) supplement every 15 minutes that was matched in texture and taste but had no caloric value. Arterial glucose levels were well-maintained with the CHO supplement, but decreased from 5.2 mmol $\bullet L^{-1}$ to 2.9 mmol $\bullet L^{-1}$ with the PLA supplement. For one subject in the PLA trial who was unable to maintain the assigned workload (220 Watts) during the last 45 minutes, the workload was decreased to 100 Watts allowing the subject to finish the trial. All other subjects in both the CHO and PLA trials were able to finish the assigned workload but significant increases in RPE ($p<0.05$) were noted at the end of the PLA trial. This study demonstrated that exercise induced hypoglycemia reduces cerebral metabolic rate leading to fatigue. Therefore, during prolonged exercise, the rate at which fuels can be metabolized to provide energy for the CNS is largely dependent upon the substrate availability, with CHO being the optimal substrate.

In sum, CHO feeding during exercise has been shown to improve endurance performance for a variety of physiological reasons. The uptake of blood glucose is important during exercise because it provides energy toward the synthesis of ATP (Coyle et al., 1983). Another benefit to oral consumption of a CHO supplement during exercise is it's potential in mitigating an increase in muscle ammonia production.

Research by Snow et al. (2000), showed that carbohydrate ingestion attenuates muscle and plasma ammonia accumulation during the latter stages of sub maximal exercise. A decrease in serotonin levels inside the CNS is another benefit to CHO intake during exercise. CHO ingestion can help reduce CNS serotonin levels by increasing the secretion of insulin which blunts the release of FFA and free tryptophan (Karelis, et al., 2010). Finally, the most readily available fuel source for the brain is blood glucose. Therefore, preventing hypoglycemia through the consumption of CHO during in endurance activity is another possible mechanism for delaying fatigue (Nybo et al., 2003).

Benefits and Physiological Responses of CHO-P Supplementation during Recovery

Not all sport drinks contain just water, sugar and electrolytes. Research has shown that CHO-P supplementation during recovery from endurance activity generates physiological benefits (Howarth, Moreau, Phillips, & Giballa (2008).

Williams, Raven, Fogt, and Ivy (2003), conducted a pair of studies that looked at the benefits of a CHO-P and CHO supplementation on endurance performance after a short recovery period. The two studies followed identical protocol but were conducted in different locations with different subjects. For both studies, 8 trained male cyclists were recruited and were familiarized with the testing protocol. Prior to cycling a 20-gauge catheter was inserted into the subject's forearm. Subjects then cycled for 2 hours at 65-75% VO2max to deplete muscle glycogen and to lower blood glucose levels. If after 2 hours of cycling subjects blood glucose levels had not declined below 4 mmol $\bullet L^{-1}$, 5-minute sprints at 85% VO2max were performed with 5 minutes at 75% VO2max between each sprint until the adequate reduction in blood glucose was reached. Following the completion of exercise, subjects consumed either 355 mL of a CHO-P (Endurox) beverage, or 355 mL of a CHO sports beverage (Gatorade). After a 4-hour recovery periods, subjects then performed a ride to exhaustion. An exercise intensity of 85% VO2max was assigned, and subjects were asked to ride until they reached exhaustion, which was defined as the point at which the pedal cadence fell below 60 rpm for 5 seconds. The combined results of these studies showed a 55% increase in performance time when subjects consumed the CHO-P beverage during recovery in comparison to the CHO supplement. It is also showed that in a short recovery setting, a CHO-P treatment increased glycogen stores by up to 128% more than that of a CHO supplement. Thus, compared to a CHO supplement, CHO-P supplementation can help accelerate the recovery process, or improve subsequent endurance performance partially due to greater muscle glycogen restoration. These results indicate that a CHO-P supplementation during intermittent endurance or ultra-endurance activity better maintains muscle glycogen levels and thus increase performance compared to a CHO supplementation. Since certain athletes train or compete multiple times in a short period makes this study very practical particularly for track and field athletes who race multiple times in the same day.

One possible benefit of CHO-P is enhanced protein synthesis in recovery. Howarth, et al., (2008) looked at the effects of CHO-P supplementation on skeletal muscle protein synthesis during recovery from exercise. They studied six healthy males with a mean age of 22 ± 1 year, mass 90 ± 5 kg, height 184 ± 2 cm, and body mass index of 26.4 ± 0.8 kg/m^2. Subjects were habitual exercisers, but none of them were training for a specific event or competition. A preliminary test measured VO2max measured via an incremental protocol on an electrically braked cycle ergometer (mean 4.4 ± 0.3 L/min). After which, subjects performed three experimental trials in random order and on three days separated by at least 7 days while consuming either a low carbohydrate supplement (LCHO, 1.2 g/kg/

hr CHO), a CHO-P supplement (1.2 g/kg/hr CHO, 0.4 g/kg/hr protein), or a high carbohydrate supplement (HCHO, 1.6 g/kg/hr CHO). Each experimental trial consisted of a 2-hour bout of exercise consisting of 12 10-minute stages that alternated between 50% $Vo2_{peak}$ and 80% $Vo2_{peak}$, followed by a 4-hour recovery period in which one of the three supplements was ingested at a rate of 750 ml/h in 15-minute increments for the first 3 hours of recovery. The trials were separated by 7 days, and each subject was asked to maintain a constant habitual exercise and dietary pattern throughout the course of the study. On the day of each trial, subjects were weighed and a catheter was inserted into an antecubital vein. Resting blood sample were taken followed by a baseline breath sample to measure carbon dioxide output (Vco2). Immediately following the exercise protocol, a muscle biopsy was taken from the vastus-lateralis muscle. The muscle sample was immediately frozen and stored for later analysis of glycogen levels, amino acid levels, and mixed muscle fractional synthetic rates (FSR). The results of this study showed that mixed muscle FSR was significantly higher during recovery ($P < 0.05$) in the CHO-P group in comparison the both the LCHO and HCHO groups. However, there was no significant difference in muscle glycogen synthesis rates amongst the 3 groups (LCHO: 23 $\pm$ 3, HCHO: 25 $\pm$ 7, CHO-P: 25 $\pm$ 4 mmol/kg/hr). There was no difference between the groups for blood glucose or serum insulin however levels of blood glucose and serum insulin were greater after 60-180 minutes of recovery in comparison to post-exercise levels. In conclusion, mixed muscle FSR was greater with the ingestion of protein and CHO during recovery from endurance exercise compared to supplements matched with similar CHO content and similar caloric content.

Benefits and Physiological Responses of CHO-P Supplementation during Endurance Activity

While some research supports CHO-P supplementation as a means for aiding recovery, research using CHO-P supplementation as a means of fueling during prolonged endurance activity is a relatively scarce and inconclusive. The addition of protein to a CHO supplement is thought to aid in performance for a couple of reasons. For one, CHO-P is thought to stimulate glucose transport by enhancing insulin levels. Also, the maintenance of Krebs Cycle Intermediates is another mechanism by which CHO-P may increase endurance performance. McCleave et al. (2011), looked at the effects of CHO-P supplementation during prolonged exercise. They hypothesized that a 3% CHO + 1.2% protein mixture would improve time to exhaustion (TTE) in comparison to a traditional 6% CHO mixture. Fourteen female endurance cyclists and triathletes were asked to complete a 3-hour cycling protocol at varying intensities (45% and 70% VO2max) followed by a performance ride to exhaustion at an intensity set to their ventilation threshold (VT). The average intensity for the performance ride was 75.06% VO2max and there was a significant increase in TTE in the CHO-P (49.94 ± 7.01 minutes) supplement group compared to that of a CHO group (42.36 ± 6.21 minutes) despite having 50% of the CHO content and 33% fewer total calories.

The effects of CHO-P supplementation were also investigated by Ferguson-Stegall et al. (2010). They tested 15 (8 male, 7 female) endurance trained athletes (cyclists and triathletes) between the ages of 20 and 40 who were accustomed to cycling for prolonged periods at a time (3-6 hours in a single ride). The study design consisted of 2 double blinded, randomly ordered, trials in which the subjects would consume 275 ml of either a 6% CHO mixture or a 3% + 1.2% CHO-P mixture every 20 minutes throughout the duration of the exercise protocol. Subjects cycled for 30 minutes at 45% VO2max as a warm up. During the next 1.5 hours subjects cycled at alternating intensities of 45% and 70% VO2max every 8 minutes. After 1.5 hours, cycling intensity continued to alternate between 45% and 70% VO2max for the next hour, but in 3-minute increments. Once the 3-hour mark was reached, subjects were asked to cycle to exhaustion at an intensity between 74% and 85% VO2max while maintaining a pedaling cadence of 80-90 rpm. Exhaustion was defined as no longer being able to maintain 60 rpm. TTE was recorded as the minutes and seconds beyond the 3-hour point. Ventilatory threshold (VT) was calculated after the test was completed to see if differences in performance occurred below or above this level. This study showed that for the combined group (all 15 subjects) TTE was increased with the CHO-P treatment (31.06 ± 5.76, & 26.03 ± 4.27 min) but the increase was not statistically significant ($p=0.064$). This implies that the results were not gender dependent. However, TTE was significantly improved in the CHO-P subjects who exercised at intensities below their VT ($p=0.006$). Therefore, other factors that contribute to fatigue at higher exercise intensities such as decreased muscle pH and the depletion of high energy phosphates may not be affected by the supplementation. In a 2001 review article, Stackhouse, Reisman, and Binder-Macleod emphasize the role of pH in skeletal muscle fatigue. They stated that when the rate of pyruvate production (from glycolysis) is greater than the rate of pyruvate oxidation (from tricarboxylic acid cycle) the excess pyruvate will lead to an accumulation of excess protons (H^+ ions). This increase in proton accumulation leads to a decrease in pH, which may potentially reduce muscle force by decreasing calcium (Ca^{2+}) release from the sarcoplasmic reticulum, decrease the sensitivity of troponin-C to CA^{2+}, and by potentially interfering with cross-bridge cycling. All of which are critical in order to maintain muscular contraction and avoid fatigue (Stackhouse, Reisman, & Binder-Macleod, 2001).

In 2003, Ivy, Res, Sprague, and Widzer looked at the performance benefits (TTE) of adding protein to a traditional CHO supplement in cycling at varying intensities. This study was the first to utilize this specific exercise protocol, which was then repeated in the two above studies by McCleave et al. (2011) and Ferguson-Stegall (2010). Ivy et al. (2003) tested 9 trained male cyclists between the ages of 22 and 30. These individuals were highly trained with an average VO2max of 61.3 ± 2.4 ml/kg/min. This selection of subjects, as well as a similar selection in other studies, guided the authors of the current paper in creating their selection criteria. After a 12-hour fast, subjects were asked to cycle to fatigue on 3 separate occasions. The 3 trials were spaced a minimum of 7 days apart. The exercise protocol contained a 30 minute warm-up at 45% VO2max followed by cycling 6 times for 8 minutes at 75% VO2max alternated with 8 minutes at 45% VO2max. Next, the subjects performed 9 repetitions of the same alternating intensities in 3 minute intervals. Fatigue was defined as the point at which a subject could not maintain the required intensity for 15 seconds despite verbal encouragement. Immediately prior to the study, and every 20 minutes thereafter subjects received 200 mL of either a flavored aspartame-sweetened placebo beverage (PLA), a 7.75% liquid carbohydrate mixture (CHO), or a 7.75% carbohydrate/1.94% protein mixture (CHO-P). Supplements were administered until exercise intensity for each subject reached 85% VO2max, thereafter no supplementation was provided. The results of this study showed a 55% increase in TTE in the CHO trial compared to the PLA trial, and a 36% increase in the CHO-P trial compared to the CHO trial. Mechanisms for the improvement were not fully understood as mean blood glucose levels between CHO and CHO-P groups were not different. However, at the point of fatigue there was a slight, but non-significant, increase in blood glucose concentrations in the CHO-P group (3.96 ± 0.2 mmol $\cdot L^{-1}$) compared to the CHO group (3.79 ± 0.19 mmol $\cdot L^{-1}$). It is very unlikely that an increase in performance in the CHO-P treatment was simply due to a better maintenance of blood glucose concentrations because the increase in concentration was insignificant. Rather, the authors speculated that the addition of protein to a CHO supplement could help maintain Krebs cycle intermediates in the skeletal muscle. As exercise progresses, Krebs cycle intermediates begin to diminish and the ability of the mitochondria to support aerobic energy production is decreased.

Another potential benefit to consuming protein during exercise is that it plays an important role in maintaining the fluid-electrolyte balance, because albumin allows fluid to flow in and out of cells to maintain oncotic pressure. Maintaining this pressure is vital for adequate distribution of fluid throughout the body which allows for the transport of nutrients. This is important for endurance athletes due to the large amounts of sweat that may be lost during activity (Lamont, 2003). Catchart, Murgatroyd, Mcnab, Whyte, and Easton (2011) found subjects consuming CHO-P supplementation had less increase tympanic membrane temperature during endurance competition in the heat in comparison to CHO supplementation (1.2 ± 0.1 and 1.5 ± 0.1 Celcius Degrees). Furthermore, the consumption of protein is thought to decrease the release of serotonin because BCAA's and free tryptophan (fTryp) compete for the same receptors. However, research in this area has been very inconclusive. In a recent review article, Blomstrand (2000) points out that prior studies have shown that there is a decrease in performance with protein consumption due to an increase in ammonia production. Blomstrand et al. (1997) compared the RPE values of 7 male cyclists who consumed either a protein (PRO) or a non-protein placebo (PLA) supplementation. The PRO supplement was an aqueous solution with no carbohydrates and the placebo was matched for taste and consistency with no protein or caloric value. The 7 male cyclists in this study performed a 60-minute ride on a cycle ergometer at 70% of their VO2max. This was followed by a 20-minute ride at maximal effort. Throughout the exercise, subjects consume 6-8 grams of protein at their own pace. Although means and standard deviations were not provided the results showed lower RPE values when subjects consumed the PRO supplement in comparison to the PLA.

However, in a study by Toone and Betts (2010), no significant differences in performance were found by adding protein. Twelve competitive male cyclists and triathletes (age 23.4 ± 3.2 years, body mass 72.5 ± 5.2 kg, $VO2_{max}$ 64.3 ± 6.4 ml;/kg/min) participated in 2 trials in a randomized, double blinded, order. 15 minutes before the exercise protocol began, participants were asked to consume 7 ml/kg of either a 9% CHO solution or a 6.8% + 2.2% CHO-P solution. Following the consumption of the supplement, participants would begin a 10-minute warm up on an electronically braked cycle ergometer at 60% $VO2_{max}$ followed by a 45-minute variable intensity exercise protocol. This protocol was performed in 3, 15-minute exercise blocks at intensities between 60% and 90% $VO2_{max}$, which has been shown to effectively deplete glycogen from both Type I and Type II muscle fibers (Toone & Betts, 2010). Following the variable intensity exercise protocol, participants consumed an additional 2.5 ml/kg of the prescribed supplement before engaging in a 6-km time trial. The results of this study showed a decrease in performance when consuming a CHO-P beverage versus. a CHO beverage (438 ± 22s & 433 ± 21s respectively). However, this 0.94% decrease in performance was not statistically significant (p= 0.048).

One of the reasons for the variation in results are differences in methodology particularly the type and volume of supplementation, between the studies. Some studies used an isocaloric supplementation whereas others used an isocarbohydrate supplementation. This could lead to varying results because with an isocarbohydrate study it is possible that the performance benefits came from the increased number of calories rather than the protein content of the supplement. Another major reason for gaps in the research is that some studies used a time to exhaustion (TTE) method whereas others used a time trial (TT) method (Coletta, 2011).

Summary

Current research has looked at the physiological advantages provided by various forms of CHO supplementation compared to water during exercise, More recently, research studies have looked at CHO-P compared to a CHO supplementation during endurance exercise. While the benefits of CHO over water supplementation are consistently supported the value of CHO-P compared to CHO is less clear. While the results from the body of research involving CHO-P supplementation are inconclusive, further be studied utilizing varying methodologies may be needed. Reasons for these inconclusive findings are numerous, and these gaps in research provide rationale for further investigation into this problem. Although some research has shown improved endurance performance with CHO-P supplementation during activity (Ferguson-Stegall, 2010; Ivy et al., 2003; & McCleaveet al., 2011), others have not (Bloomstrand, 2000, & Toones & Betts, 2010). One glaring gap in the research is that there is a lack of studies done on endurance runners. Most of the research mentioned in this chapter focused on cycling performance. Literature using field studies is also very scarce. Laboratory settings tend to be more controlled and convenient, thus most of the literature was conducted in laboratory settings. Unfortunately, this lends itself to being somewhat impractical when speaking of true endurance performance because most endurance competitions are not in controlled environments and the lack of motivation and encouragement that comes from competing alongside other athletes in a race-like situation. Finally, a majority of research has utilized the time to exhaustion form of methodology. Research using the time trial methodology is much limited. Thus, the purpose of the current study was to add to the existing literature by bridging these gaps and helping to provide evidence as to whether the addition of protein to a CHO supplement will improve RPE and finishing speed of an endurance run in a non-laboratory setting.

Chapter III

Methodology

This study examined the performance benefits of two commercially available sports beverages in highly trained male distance runners. The purpose of this chapter is to describe the: (a) participants, (b) setting, (c) instrumentation, (d) procedures, (e) data collection, and (f) data analysis.

Participants

Invitations to participate in this study were extended to 11 members of the Eastern Illinois University (EIU) Men's Cross-Country team. This group of participants was selected due to their high level of distance running training. Female athletes were excluded from this study due to the lack of healthy female participants available. In addition, the participant's fitness level and training habits were well known to the primary researcher. All participants followed the similar training regimens prior to the study, as well as in between each trial. The number of participants was limited by the small number EIU Cross-Country Team members. Furthermore, nine members of the team were still competing in their season and were not permitted by the coaches to participate in the study. To be eligible to participate, participants were required to be able to complete two, 13.1 mile runs on separate days while consuming a commercially available sport beverage that was provided by the primary researcher. Participants must also have been free from any injury in which they were unable to fully train for more than 7 consecutive days at any point within the past 3 months. The later criterion excluded two of eleven participants results in a final number of 9 participants. The descriptive statistics for the participants age can be found in Table 1.

Table 1: Participant Descriptive Data

Group	Age (years)		BMI	
	Mean	SD	Mean	SD
CHO	21.00	4.08	21.48	0.60
CHO-P	19.20	1.30	20.89	1.97
Total	20.00	2.83	21.15	1.48

Note: Where BMI = Body Mass Index, SD = standard deviation, CHO = Carbohydrate Sport drink, and CHO-P = Carbohydrate + Protein Sport Drink

Permission to recruit athletes from the EIU Men's Cross Country team was obtained from the head coach prior to approaching the athletes. The study was approved by the Eastern Illinois University Institutional Review Board regarding research with human subjects and all participants gave their voluntary informed consent prior to participation.

Prior to the first trial of the study, all participants were randomly assigned to consume one of two sport drinks for Trial 1, a 4-ounce beverage with 10.15 g of carbohydrates and 0 g of protein (CHO) or a 4-ounce beverage with 7 g of carbohydrates and 1.67 g of protein (CHO-P). Subjects consumed the other sport drink in Trial 2 (See Table 2). These specific amounts were used to further investigate prior research by Toone and Betts (2010) that used a 9% CHO supplement and a 6.8% + 2.2% CHO-P supplement. This created two isocaloric sport drinks with the CHO having 40.11 calories per serving and the CHO-P having 40.00 calories per serving allowing the primary researcher to accurately look at the benefits of protein as opposed to increased calories. For analysis purposes the data was separated into four groups (See Table 2). This allowed the researcher to evaluate any intergroup differences that may have occurred in this study.

Table 2: Grouping of Subjects for Analysis Purposes

Group Name	Sport Drink	Number of Participants (Individual Number)
CHO1	Carbohydrate Trial 1	4 (248, 246, 244, 238)
CHO-P1	Carbohydrate Protein Trial 1	5 (241, 243, 245, 247, 249)
CHO-P2	Carbohydrate Protein Trial 2	4 (248, 246, 244, 238)
CHO2	Carbohydrate Trial 2	5 (241, 243, 245, 247, 249)

Note: Where CHO1 = Carbohydrate Sport Drink consumed in Trail 1, CHO-P1 = Carbohydrate + Protein Sport Drink consumed in Trial 1, CHO2 = Carbohydrate Sport Drink consumed in Trail 2 and CHO-P2 = Carbohydrate + Protein Sport Drink consumed in Trial 2.

Setting and Weather

Data collection occurred at the west to east Lincoln Prairie Grass Trail in Coles County on two consecutive Sunday's in November. The weather on the first trial was 42 degrees Fahrenheit (F) with a N/NE wind of 12 mph (The Weather Channel, 2012). This was very similar to the weather for the second trial when the temperature was 43 F with a N/NW wind of 4 mph. The temperature differed by only one-degree F and the wind speed was only 8 mph higher on the second day.

Instrumentation.

The following instruments were used for data collection: (a) GPS stopwatch, (b) two primary stopwatches and two backup stopwatches, (c) camera with video capability, (d) bib numbers, and (e) Borg 1-10 scale.

GPS stopwatch. GPS stopwatches are often used by runners to measure the distance of their runs. The Garmin 305 GPS stopwatch (Garmin Ltd., 2008) was used to measure the length of the course used in this study. The reason this particular model was used was due to its GPS reliability of ± 19 feet (Garmin Ltd. 2008) and its ease of use. The primary researcher already owned this model of watch, making him very familiar with how to utilize the device to accurately measure the route.

Stopwatches. Stopwatches were used to measure elapsed time. They are practical tools for monitoring the length of time it takes an individual to run a particular distance. The Sprint 8 stopwatch was used as the primary stopwatch at two locations in this study. One was used to measure the time it took the participants to complete the first 12 miles of the run. The second Sprint 8 was used to measure the overall time it took participants to complete the run. This allowed the researcher to calculate the last 1.1 mile split. The Sprint 8 model was used for its ease of use, validity, and reliability, which have been documented in the Sprint 8 timer manual (TimeTech USA, 1997). Backup stopwatches were also used to ensure times would be recorded in the event of primary stopwatch malfunction.

Camera. Video-recording was used to ensure accuracy of the order of finish. In addition, a Canon camera with video capabilities was used at the 12-mile mark to ensure that the last 1.1 mile split was measured accurately for each individual. This allowed the researcher to go back and assure that the order of participants and times were recorded properly.

Bib numbers. Bib numbers were used to help identify participants at various points in the course. The bib numbers allowed those involved in the data collection to properly identify the participants at the 12-mile mark and at the finish to allow for better accuracy in recording placement (at 12-mile mark) and order of finish. Members of the research team were also able to collect RPE values and times for each participant with ease. Therefore, the use of bib numbers helped ensure the overall accuracy of the data collected in this study.

Borg CR 10 scale. For this study the Borg 0-10 RPE scale was used to measure rating of perceived exertion (RPE). This scale was utilized due to its practicality, it was easy for runners to hold up numbers on two hands as they ran. Many of the runners were already familiar with this scale as it is a commonly used method of measuring exertion during hard workouts for cross country runners. However, all participants were familiarized with the scale prior to each trial.

Procedures

Prior to the collection of data, numerous procedures were implemented to ensure the collection of data was done as accurately as possible. The primary researcher, his parents, and undergraduate/graduate students made up the research team. Members of the research team had prior experience in timing and collection of RPE. In addition, members of the research team met with the primary researcher to ensure they all understood their role in the data collection process. At this time, all questions and concerns that members had for the primary researcher were addressed. Members of the research team were assigned the same role at both trials.

A meeting with the participants occurred prior to the start of the first trial. Participants were instructed on the details of the testing protocol including at what points they would consume supplementation (miles 3, 6, and 9) and how to accurately give their ratings of perceived exertion. At this time, participants were also instructed that they were to give a moderate training effort for the first 12 miles of each trial prior to running the last 1.1 miles as hard as they could. This process was briefly repeated immediately before each trial.

The course used in this study was also selected very purposefully. Participants had often trained on this trail, thus giving them a level of familiarity with the terrain and course.

The weather was monitored closely in the days leading up to each trial. The primary researcher utilized the website weather.com (https://

www.weather.com) 3 times daily for 7 days leading up to each trial to monitor radar and weather conditions. In order to limit extraneous variables, the trials were to occur on days with similar weather. Had there been a difference of more than 10 mph in wind direction, or rain, or a significant increase or decrease in temperature of more than 10 degrees, the second trial would have been moved to another day of similar weather within the next week.

To enhance the accuracy of this study, the route was measured and marked prior to the collection of data. The primary researcher measured the route with a Garmin 305 GPS watch, and marked locations for the start/finish line, each aid station (miles 3, 6, and 9), and the 12-mile mark with small flags set into the ground off to the side of the course. This helped ensure that the aforementioned spots at miles 0, 3, 6, 9, 12 and 13.1, would be placed at the same location for each trial.

The day before each trial, the sport drinks were prepared by the primary researcher according to the content shown in Table 3. Both the CHO and CHO-P sport drinks contained a combination of sucrose, fructose, and dextrose as their primary carbohydrate sources. The protein content of the CHO-P sport drink contained a mixture of whey concentrate and BCAA. Percentages of the carbohydrate and protein forms in both sport drinks were undisclosed by the manufacturer.

Table 3: Nutrient Composition of Sports Drinks

	CHO	CHO-P
Servings Size	4.00 oz	4.00 oz
Calories	40.11 kcal	40.00 kcal
Carbohydrates	10.15 g	7.00 g
Protein	0.00 g	1.67 g

Note: Where CHO = Carbohydrate Sport Drink, CHO-P = Carbohydrate + Protein Sport Drink, kcal = calories per serving, oz = ounces per serving, and g = grams.

Data Collection

Data were collected on two consecutive Sundays in November. Participants met at the Coles County Fairgrounds at 9:30 a.m. on both days. Instructions were given prior to each trial and the participants walked/jogged to the starting line approximately 0.2 miles away. Each trial was started by the primary researcher giving the "Go" command and the timing device was simultaneously started. Each trial consisted of a 13.1-mile out-and-back back run starting from the east, running west, and returning back to the east. Therefore, the 1.1-mile time trial portion of the trial was run in a west to east direction back to the starting line. A member of the research team immediately drove to the 12 mile mark to collect time that was used to calculate this 1.1-mile time trial. Runners were instructed to run at an honest training pace for the first 12 miles before finishing the last 1.1 miles at as fast as possible. Words of encouragement were also given at the 12 mile mark to help aid participants in giving a maximum effort. Sport drinks were administered by the primary researcher at aid stations at mile markers 3, 6, and 9. Upon the start of each trial, members of the research team immediately drove to the halfway point to collect RPE data. At the halfway point, members of the research team would ask the participants to put a number up on their hands from 1-10 to measure their exertion level. This data was immediately recorded onto a pre-printed data collection sheet provided by the primary researcher. The research team then drove back to the finish line to collect the RPE data at the finish in the same manner.

Administration of sports drinks. Sports drinks were precisely measured and monitored at each aid station. As the participants were completing the trial, the primary researcher rode a bicycle ahead of the participants to each aid station. Aid stations were set up every 3 miles prior to the time trial portion of the study at mile markers 3, 6, and 9. At the aid station a table was set up with sport drinks pre-measured into 4 oz. servings and placed into plastic cups. The cups were color coordinated for each group. Participants were made aware prior to each trial of which color cup they were to consume throughout the trial. The primary researcher then stayed to monitor the aid station to ensure that the participants followed the testing protocol properly by consuming all of their assigned beverage prior to moving on to the next aid station.

Data Analysis

Data were analyzed using SPSS (International Business Machines Corporation, 2012, version 22.0) utilizing a significance level of alpha = 0.05. A Multivariate Analysis of Variance (MANOVA) with a Tukey post-hoc test was performed to analyze intergroup differences among sport drink groups for RPE and finishing speed of an endurance run. Descriptive statistics were also measured for all the participants.

Chapter IV

Results

The purpose of this study was to compare running performance and levels of perceived exertion in highly trained endurance athletes when consuming a CHO-P sport drink to consuming a traditional CHO sport drink. The time to complete the last 1.1 miles (time trial) of the 13.1-mile course and the exertional perception benefits measured by RPE utilizing the Borg 0-10 Scale were compared between two trials; one where participants were consuming a CHO-P sport drink and the other where participants were consuming a common CHO sport drink on two consecutive Sundays in November.

Perceived Exertion

Perceived exertion was assessed by collecting RPE, on a Borg CR 10 scale, at both the halfway point (RPEH), and at the completion (RPEF) of each 13.1-mile time trial run. Descriptive statistics for RPE are shown below in Table 4. A MANOVA analysis was used to measure intergroup statistics for the study. The overall MANOVA had a significance of 0.766 according to the Wilks' Lambda coefficient, indicating that there was no statistical significance in time and RPE between the two sport drink groups. However, for the purpose of this paper a Tukey post-hoc test was still utilized to evaluate intergroup differences in further detail.

Table 4: ***Mean RPE Scores Among Sport Drink Groups***

Variable	Group	Mean	±SD	N
RPEH	CHO1	2.50	1.00	4
	CHO-P1	2.80	1.48	5
	CHO-P2	3.25	1.71	4
	CHO2	2.60	2.30	5
RPEF	CHO1	6.75	0.50	4
	CHO-P1	7.40	0.89	5
	CHO-P2	7.88	1.18	4
	CHO2	7.50	0.71	5

Note: Where SD = standard deviation, RPEH = rating of perceived exertion at halfway, RPEF = rating of perceived exertion at the finish, CHO1 = Carbohydrate sport drink consumed in Trial 1, CHO-P1 = Carbohydrate + Protein sport drink consumed in Trial 1, CHO2 = Carbohydrate sport drink consumed in Trial 2, & CHO-P2 = Carbohydrate + Protein sport drink consumed in Trial 2.

Intergroup differences for RPEH and RPEF were analyzed among the four groups (CHO1, CHO-P1, CHO-P2, and CHO2). A Tukey post-hoc test showed no significant difference among the group comparisons. The intergroup p-values, as seen in Table 5, showed that the values for the groups did not differ. This lack of intergroup difference was anticipated after seeing the similarity in mean RPEH values for each group. RPEF data showed a similar pattern to that of RPEH as there were no significant differences observed among the group comparisons. The p-values for RPEF intergroup differences are found in Table 5.

Table 5: Intergroup Differences *for RPE Scores Among Sport Drink Groups*

Variable		Comparison Group	P Values
RPEH	CHO1	CHO-P1	0.994
		CHO-P2	1.000
		CHO2	0.926
	CHO2	CHO-P1	0.979
		CHO-P2	0.942
	CHO-P1	CHO-P2	0.998
RPEF	CHO1	CHO-P1	0.673
		CHO-P2	0.570
		CHO2	0.284
	CHO2	CHO-P1	0.998
		CHO-P2	0.991
	CHO-P1	CHO-P2	0.838

Note: Where RPEH = rating of perceived exertion at halfway, RPEF = rating of perceived exertion at the finish, CHO1 = Carbohydrate sport drink consumed in Trial 1, CHO-P1 = Carbohydrate + Protein sport drink consumed in Trial 1, CHO2 = Carbohydrate sport drink consumed in Trial 2, & CHO-P2 = Carbohydrate + Protein sport drink consumed in Trial 2.

While it is evident that there is a greater difference between the two groups at the finish compared to the halfway point, none of the finish values were statistically significant. However, the CHO-P groups show a slight trend towards a higher RPE. In summary, there was no significant difference in perceived exertion observed between running trials when athletes were supplemented with a carbohydrate and protein based sport drink and a carbohydrate only based sport drink.

Running Performance

Running performance was assessed as the total time required to complete the last 1.1 miles of the 13.1-mile endurance run. This was considered the "Time Trial" portion of the research study and was utilized to evaluate finishing speed in this study. Comparisons among groups were analyzed for the "Time Trial" in the same manner that they were analyzed for RPE (CHO1, CHO-P1, CHO2, CHO-P2). Every participants had a faster time trial time in trial 2 than they had in trial 1 regardless of the sport drink they consumed. This is reflected in the descriptive statistics for physical performance (Table 6).

Table 6: *Mean Time Trial Performance Scores among Sport Drink Groups*

Variable	Group	Time(sec)	±SD	N
Time Trial Time- Trial 1	CHO1	353.39	19.23	4
Time Trial Time- Trial 1	CHO-P1	361.36	19.73	5
Time Trial Time- Trial 2	CHO-P2	340.79	27.51	4
Time Trial Time- Trial 2	CHO2	346.70	18.50	5

Note: Where SD = Standard Deviation, N = Number of Participants,CHO1 = Carbohydrate sport drink consumed in Trial 1, CHO-P1 = Carbohydrate + Protein sport drink consumed in Trial 1, CHO2 = Carbohydrate sport drink consumed in Trial 2, & CHO-P2 = Carbohydrate + Protein sport drink consumed in Trial 2.

Intergroup differences for physical performance, measured as the time required to complete the 1.1-mile time trial, were analyzed by using a Tukey post-hoc test. The intergroup p-values showed that there was no significant difference between the groups. The lack of a significant difference in time is supported by a similar lack of a significant difference in RPE. The p-values for intergroup differences for Time are shown in Table 7.

Table 7: ***Intergroup Differences for Time Trial Performance Scores among Sport Drink Groups***

	Comparison Group	P Values
CHO1	CHO-P1	0.942
	CHO-P2	0.964
	CHO2	0.835
CHO2	CHO-P1	0.700
	CHO-P2	0.975
CHO-P1	CHO-P2	0.494

Note: Where CHO1 = Carbohydrate sport drink consumed in Trial 1, CHO-P1 = Carbohydrate + Protein sport drink consumed in Trial 1, CHO2 = Carbohydrate sport drink consumed in Trial 2, & CHO-P2 = Carbohydrate + Protein sport drink consumed in Trial 2.

Summary

Overall, there were no significant differences between the two sport drink groups for either ratings of perceived exertion or time trial running time observed in this study.

Chapter V

Discussion, Conclusions, & Recommendations

The purpose of this study was to investigate the effects of a CHO-P sport drink consumed during a 13.1 mile endurance run compared with a CHO only sport drink on RPE and finishing speed. It was hypothesized that the consumption of a protein containing CHO sport drink during a 13.1 mile running performance would improve finishing speed in highly trained endurance runners more so than that of a simple CHO sport drink. Furthermore, it was hypothesized that CHO-P would lower RPE midway through and at the end of the same performance. The rationale behind this hypothesis was based upon evidence of physiological benefits associated with the consumption of protein during endurance events such as the potential inhibition of serotonin release and thus delaying fatigue and improving performance (Davis et al., 2000). Highly trained endurance athletes performed two 13.1 mile runs consuming either a CHO or CHO-P sport drink every 3 miles. The first 12 miles of each run were at a traditional training pace with the last 1.1 miles at a race effort. This 1.1-mile time trial segment was used in the data analysis to determine if the addition of protein to a CHO sport drink helped improve finishing speed at the end of an endurance run. RPE was also recorded at both the halfway point and finish to analyze the effects of the addition of protein to the sport drink in terms of perceived exertion as an indicator of possible CNS fatigue. The data was then analyzed by a

MANOVA looking at intergroup differences. The analysis showed there were no significant differences (P>0.05) in RPE or running time between the groups.

Discussion

The results of this study showed that CHO-P sport drink did not lower RPE or improve finishing speed at the end of an endurance run more than that of a CHO sport drink. This confirms the findings from Toone and Betts (2010) in which no improvement in cycling time trial performance was found when participants consumed isocaloric CHO or CHO-P supplements. A study by Richardson et al., (2012) also showed no improvements in cycling TTE when participants consumed isocaloric CHO and CHO-P supplements.

Although the differences were statistically insignificant, there are still a few observations and trends to the data which are noteworthy. One thing not measured was that following the final trial, the primary researcher asked how each participant felt after consuming the sport drinks in each trial. Eight of the nine participants reported feelings of "having more energy" and "feeling rejuvenated" when consuming the CHO-P beverage. This was reported to the primary researcher immediately after participants caught their breath following the final trail and prior to the participants knowing which sport drink they consumed during each trial. This is noteworthy in the sense that while overall RPE didn't corroborate any significant findings during the race, there appeared to be a perceived mental benefit from the addition of protein in terms of how the majority of participants perceived their effort from a post-race perspective. If the addition of protein can help attenuate perceptual fatigue then, in theory it could be expected that there would be improvements in finishing speed at the end of an endurance run. However, the results of this study demonstrated that the addition of protein to a CHO sport drink had no effect on perceived exertion and finishing speed at the end of a 13.1 mile endurance run.

Many factors may have influenced the outcome of this study. One issue that the primary researcher noticed was that participants seemed to have given a much better effort on trial 2 than in trial 1. Participants seemed to be in a more competitive spirit and challenged one another on trial 2 compared to trial 1. There was significantly less talking in the 1-2 miles leading up to the time trial in the second trial. The data also showed that every participant ran faster on the second trial regardless of the sport drink they were consuming. This could have impacted the finishing speed and increased RPE values as well. Part of the problem with using human subjects, and athletes more importantly, is the challenge of obtaining valid RPE values. Highly trained endurance runners are trained to ignore fatigue. This limits the accuracy of RPE as a way of measuring physical exertion however due to its wide acceptance and ease of use, it was deemed the best means for measuring exertion for this study. Still, most of the participants reported to the primary researcher descriptive perceived exertion terms of feeling "rejuvenated" or "more energized" after consuming the CHO-P beverages. This lead the primary researcher to believe that the Borg CR 10 scale may not have been a valid tool for the purposes of this study.

The weather, while similar was slightly different during trial 2. The wind was coming more of a head/crosswind in the first trial, and a tail/crosswind in trial 2. A tailwind could help improve finishing speed by helping runners exhaust less energy to run a given pace. This assistance can be even more critical in the late stages of a race, when fatigue is beginning to set in. Combining this with the added effort could have played an important role in skewing the data.

Also, the higher amount of carbohydrates in the CHO sport drink could have also influenced the study. There are significant physiological benefits of consuming carbohydrates during endurance activity such as maintaining blood glucose availability in the body. This is critical because blood glucose becomes the body's primary fuel source during prolonged endurance activity (Coggan & Coyle, 1991). The CHO-P group had much less carbohydrate content, which could have led to a decreased availability of blood glucose during exercise ultimately putting them at a disadvantage. A change in methodology by utilizing isocarbohydrate sport drink mixtures might be needed in future studies to further investigate the potential benefits a CHO-P sport drink may have on finishing speed at the end of an endurance run. Overall, there are a variety of factors that influenced the data, thus leading us to believe more research is necessary.

Conclusion

In conclusion, there was no significant difference found in RPE and finishing speed at the end of an endurance run between a CHO-P sport drink and a CHO sport drink in highly trained distance runners.

Recommendations

The body of research on this topic is currently very limited, and results have varied. Therefore, future research on this topic should aim to address the following issues and recommendations. A more accurate, and direct way of measuring CNS fatigue could help show the benefits of protein from a mental perspective. This was evident in our findings as 8 of the 9 participants reported having feeling of improved perceived exertion such as "feeling rejuvenated" and "more energized" when consuming the CHO-P sport drink even though there was no improvements in RPE values associated with these descriptions. Utilizing a more detailed scale than the Borg CR 10 RPE scale, like the Borg 6-20 scale, would be recommended to more accurately research perceived exertion during an endurance run. A familiarization phase utilizing placebo beverages should also be a consideration for future research on this topic. The primary researcher found that every participant had a faster time on trial 2 than trial 1 regardless of sport drink. While some of this can be attributed to slight changes in weather, it could also be attributed to the participants being more familiar with the testing protocol during the second trial. Providing incentives for maximal effort during each trial is also recommended.

Formulating the drinks so that they are isocarbohydrate instead of isocaloric could also be beneficial because the CHO-P group would then not be at a significant carbohydrate deficit. While this may make it difficult to determine whether it is the added protein or added calories that is impacting the performance, the practical application of this data would be useful. An athlete wants to improve their performance regardless of whether it is due to the direct benefits of the protein or due to the body's ability to utilize more calories. Hopefully, such recommendations will help future research determine the effectiveness of adding protein sport drinks on finishing speed at the end of an endurance run.

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Appendix A

Health History Questionnaire

Assessment Testing & Prescription Lab
Eastern Illinois University - Kinesiology and Sports Studies Department

HEALTH HISTORY QUESTIONNAIRE

General Information
Name: (LAST)________________________(FIRST):____________________________
MI:__________
Address: (STREET)_________________________(Apt #)___________
(CITY)________________________(STATE)______________________(ZIP)_______
Birth Date:______________Age________Gender: (circle) M F
Student:__________Faculty___________
Phone Number:___________________________Email:_______________________

Personal Medical History
Do you have a recent or past history, or has a physician ever diagnosed you with any of the following?

______heart disease/cardiac surgery
______irregular heart beats
______defective heart valve (s)
______
______heart murmurs
______angina (chest pain)
______heart attack (MI)
______pulmonary disease
(bronchitis, emphysema, etc)
______stroke
______diabetes
______epilepsy
______high cholesterol levels

______peripheral vascular disease
______high blood pressure
______cancer type?___________
______back pain
______joint pain
(where?)________________
______migraine headaches
______asthma
exercise induced?__________
______arthritis
______lightheadedness/fainting
______fatigue

Do you smoke cigarettes? Yes: ________ No: ________
If yes, how many per day? ________
If you previously smoked, when did you quit? ____________________
How many cigarettes did you smoke daily prior to stopping? _______________

Do you drink caffeinated beverages? Yes No How much/often: ________

Do you drink alcohol? Yes No How much/ often? ________

Are you currently following a special diet? Yes No
Please specify: ______________________________

Please list any surgeries you have had and the date each surgery took place.

____

____

Please list any medications you are currently taking, the reason you are taking them, and the dosage: (including birth control) ______________________________

____

____

____

Are you allergic to any medication? Yes: ________ No: ________
If yes, please list: ______________________________
Physician's name: ______________________ Telephone: ______________
Emergency contact: ______________________ Relationship: ______________
Contact phone number: ______________________

Family Medical History
Does anyone in your family (parents and/or siblings) havea history of heart attack of heart disease (coronary artery disease)? Female relatives prior to the age of 65, male relatives prior to the age of 55: (circle) YES NO

If yes, please specify: ______________________________

______diabetes ______high blood pressure
______high cholesterol ______stroke

Exercise History
Do you currently exercise on a regular basis? (circle) Yes No
If yes, please explain what you do on a weekly basis: ______________________

____

______

Please check the total minutes you spend doing planned aerobic activity each week:
______<90 minutes ______ 90-150 minutes ______>150 minutes

What are your goals in participating in an exercise program? (check all that apply)

______ Lose weight
______Improve flexibility
______ Improve muscular strength
______ Improve muscular endurance
______Reduce low back pain
______ Increase energy levels
______ Improve overall health
______ reduce stress
______help stop cigarette smoking
______lower cholesterol
______control diabetes
______feel better overall
______tone/firm up
______other: ______________

______

I have read, understood, and completed this questionnaire. Any questions that I had were answered to my full satisfaction. I am aware that I have the right to ask to stop any test at any time.

Signature: ______________________________ Date: ______________
GA Signature: ____________________________ Date: ______________

Appendix B

Informed Consent Form

CONSENT TO PARTICIPATE IN RESEARCH

Effects of Two Different Sport Drinks on Finishing Speed at the End of an Endurance Run in Highly Trained Distance Runners

You are invited to participate in a research study conducted by Matt Feldhake and Dr. Jake Emmett, from the Kinesiology and Sports Studies Department at Eastern Illinois University.

Your participation in this study is entirely voluntary. Please ask questions about anything you do not understand, before deciding whether or not to participate.

- **PURPOSE OF THE STUDY**

The purpose of this study is to compare time trial performance, as well as perceived exertion between carbohydrate-protein supplementation and carbohydrate supplementation during endurance activity.

- **PROCEDURES**

If you volunteer to participate in this study, you will be asked to:

Fill out a full health history questionnaire to indicate that you are healthy enough to participate in this study.

Perform an endurance run on two consecutive Sundays. The runs will consist of 13.1 miles (men) or 11 miles (women). Each run will be performed at a typical training effort until the last 1.1 miles. For the last 1.1 miles in each trial you will be asked to give a complete race effort.

During each trial you will be randomly assigned to one of two supplementation groups. Every 3 miles you will be given 4 ounces of one of the two commercial sport drinks and asked to consume the contents while continuing to run. .

You will not know which supplement you are receiving each trial. The length of time to complete each trial will be ~90minutes of exercise.

We will be recording both your overall time to finish each trial, as well as the last 1.1 mile split.

- **POTENTIAL RISKS AND DISCOMFORTS**

There are very few potential risks in this study. The main risk is muscle soreness. With prolonged exercise it is very possible that muscle soreness will occur in the days following the trials

If any injury occurs, participants have access to treatment from the Eastern Illinois University Athletic Training staff.

• POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

Participants will receive some benefits from this study. This study will help participants understand optimal fueling strategies during long runs, ultimately aiding in training whether it be from a performance or solely a recovery aspect.

This study has numerous benefits to the science of distance running, and the running community as a whole. This study could provide justification for fueling with a carbohydrate-protein beverage during events such as half-marathons and marathons, as opposed to solely fueling from a carbohydrate source. This could potentially allow for distance runners, both competitive and recreational, to reap greater performance benefits both in training and competition.

• CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of coding the data. Data will be coded by use of numbers so that participants' names will not be used.

Only people directly involved in the study will have access to the data (I and my thesis committee). Per federal regulations, all research related records will be kept for at least 3 years. All records will be kept by faculty sponsor during this time in a locked cabinet or safe.

• PARTICIPATION AND WITHDRAWAL

Participation in this research study is voluntary and not a requirement or a condition for being the recipient of benefits or services from Eastern Illinois University or any other organization sponsoring the research project. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind or loss of benefits or services to which you are otherwise entitled.
There is no penalty if you withdraw from the study and you will not lose any benefits to which you are otherwise entitled.

• IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about this research, please contact:

Matt Feldhake- Phone:(217) 821-1028, Email: mjfeldhake@eiu.edu

Dr. Jake Emmett- Phone: (217) 581-7113, Email: jemmett@eiu.edu

• RIGHTS OF RESEARCH SUBJECTS

If you have any questions or concerns about the treatment of human participants in this study, you may call or write:

Institutional Review Board
Eastern Illinois University
600 Lincoln Ave.
Charleston, IL 61920
Telephone: (217) 581-8576
E-mail: eiuirb@www.eiu.edu

You will be given the opportunity to discuss any questions about your rights as a research subject with a member of the IRB. The IRB is an independent committee composed of members of the University community, as well as lay members of the community not connected with EIU. The IRB has reviewed and approved this study.

I voluntarily agree to participate in this study. I understand that I am free to withdraw my consent and discontinue my participation at any time. I have been given a copy of this form.

____
Printed Name of Participant

________________________________ ____________________
Signature of Participant Date

I, the undersigned, have defined and fully explained the investigation to the above subject.

________________________________ ____________________
Signature of Investigator Date

Appendix C

Data Collection Sheet

	Group 1= CHO1	Group 2= CHOP1				Group 3 = CHOP2	Group 4= CHO2			
Bib	Group	Height (cm)	Body Mass (kg)	BMI	Age	Total Time	12 mile time	TT Split	RPEH	RPEF
248	1									
246	1									
244	1									
238	1									
241	2									
243	2									
245	2									
247	2									
249	2									
248	3									
246	3									
244	3									
238	3									
241	4									
243	4									
245	4									
247	4									
249	4									